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1. Your reference

   9924

2. Patent application number
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   0226725.0

   15 NOV 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   BP EXPLORATION OPERATING COMPANY LIMITED
   BRITANNIC HOUSE
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   AND

   XL TECHNOLOGY LIMITED
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   BERKSHIRE, SL5 7NT
   UNITED KINGDOM

   Patents ADP number *(if you know it)*

   06225916002

   07925142001

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

   METHOD

5. Name of your agent *(if you have one)*

   COLLINS, Frances Mary

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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   PATENTS & AGREEMENTS
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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

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   a) any applicant named in part 3 is not an inventor, or
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Description	10
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Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature F.M. Collins. Date 15.11.2002

COLLINS, Frances Mary

12. Name and daytime telephone number of person to contact in the United Kingdom (01932) 763206

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METHOD

The present invention relates to a method of forming a window in the casing of a wellbore using a remotely controlled electrically powered cutting device.

Where it is desired to drill a side-track or lateral well from a selected location in a cased wellbore, it is necessary to form a window in the casing before commencing drilling of the side-track or lateral well. A window is conventionally formed in the casing of a wellbore by using a whipstock to deflect a milling device at a slight angle relative to the longitudinal axis of the wellbore so that the milling device engages with the casing of the wellbore.

However, there remains a need for an improved method and an improved device for forming a window in the casing of a wellbore.

Thus, according to a first embodiment of the present invention there is provided a method of cutting through a casing of a wellbore at a selected location in the wellbore comprising:

passing a remotely controlled cutting device comprising (a) a housing and (b) a cutting head provided with a cutting means to the selected location in the wellbore;

pivoting the cutting head on a fulcrum located on the housing about an axis transverse to the longitudinal axis of the housing so that the cutting means is positioned adjacent the wall of the casing; and

actuating the cutting means to cut through the casing of the wellbore.

According to a second embodiment of the present invention there is provided a remotely controlled cutting device for cutting through a casing at a selected location in a wellbore, the device comprising (a) a housing and (b) a cutting head provided with a

cutting means wherein the cutting head is pivotable on a fulcrum located on the housing about an axis that is transverse to the longitudinal axis of the housing and, in use, the longitudinal axis of the housing is aligned with the longitudinal axis of the wellbore, and the cutting head is pivoted on the fulcrum to position the cutting means adjacent the wall of the casing.

The casing may be run from the surface to the bottom of a wellbore. Alternatively, the casing may be run from the surface into an upper section of the wellbore with the lower section of the wellbore comprising a barefoot or open-hole completion. Preferably, the inner diameter of the casing is in the range 5 to 15 inches. A casing may also be run from the surface into a cased wellbore such that at least a section of the wellbore is provided with a first and a second concentrically arranged casing (hereinafter "double" casing). For avoidance of doubt, the cutting means is capable of cutting through such double casings.

Preferably, a hydrocarbon fluid production conduit is arranged in the wellbore in sealing relationship with the wall of the casing. Preferably, the production conduit has an inner diameter of 2.5 to 8 inches, more preferably 3.5 to 6 inches.

Suitably, the housing of the cutting device is elongate, preferably substantially cylindrical. Preferably, the outer diameter of the cylindrical housing is less than the inner diameter of the production conduit thereby allowing the cutting device to pass through the production conduit to the selected location in the cased wellbore. Preferably the cylindrical housing of the cutting device has an outer diameter of 2 to 5 inches. Preferably, the outer diameter of the cutting head is less than the inner diameter of the production conduit, preferably, 2 to 5 inches.

Preferably, the cutting device is passed to the selected location in the wellbore suspended from a cable, preferably a reinforced steel cable. Alternatively, the cutting device may be suspended from coiled tubing, for example, drill tubing or from an electric drill string. A suitable electric drill string for use in the method of the present invention is described in UK patent application number 0115524.1 which is herein incorporated by reference.

Where the cutting device is suspended from a cable, it is preferred that the cable encases one or more wires for transmitting electricity or electrical signals to the cutting device. The cable may be provided with a plurality of wires or a multiplexed wire.

Suitably, the cable may also encase one or more fibre optics for carrying signals, for example, imaging signals such as optical, infra-red, ultra-violet or ultrasonic signals from at least one sensor located on the cutting device. Alternatively, the cutting device may be provided with a separate electric cable comprising one or more wires for transmitting electricity or electrical signals and optionally one or more fibre optics.

Where the cutting device is suspended from coiled tubing, the cutting device may be provided with an electric cable that passes from the surface to the cutting device through the interior of the coiled tubing. Suitably, the cable may comprise one or more wires for transmitting electricity or electrical signals and optionally one or more fibre optics.

Where the cutting device is suspended from an electric drill string, an electrical path is provided between the cutting device and the surface as described in UK patent application number 0115524.1. It is also envisaged that the electric drill string may be provided with fibre optics for transmitting data to the surface from sensors located on the cutting device.

The term "cutting" as used herein includes milling, ablating and eroding. Thus, the cutting means is suitably a mill, an ablation means or an erosion means. Where the casing is formed from metal, the ablation means may be a laser, a means for producing an electric arc or electric spark or any other means for melting or vaporizing metal. Suitably, the erosion means may be a charge of a corrosive chemical contained in a receptacle located within the cutting device wherein the receptacle is in fluid communication with an outlet in the cutting head and the outlet is provided with an electrically actuated valve. The chemical is then squeezed out of the receptacle or jetted onto the casing. Thus, the outlet of the receptacle may be provided with a nozzle for atomizing the chemical so that an atomized jet of the chemical is directed at the casing. Alternatively, the charge of corrosive chemical may be contained in a receptacle having an explosive charge, preferably, a plurality of such receptacles. Activation of the explosive charge results in a pressure pulse and/or vaporized metal that is directed at the casing thereby cutting a hole in the casing.

Preferably, the fulcrum on the housing is a knuckle joint or a universal joint. The knuckle or universal joint allows the cutting head to pivot about an axis transverse to the longitudinal axis of the housing so that the cutting head moves into a position

adjacent the wall of the casing.

Where the cutting means is a mill or an erosion means, the cutting device may be provided with a biasing means that is actuated to urge the cutting means against the wall of the casing. Preferably, the biasing means is an elongate arm extending from the upper end of the cutting head with the longitudinal axis of the arm aligned with the longitudinal axis of the cutting head. The elongate arm may be rigidly attached to the cutting head, preferably, at or near the upper end of the cutting head. Alternatively the elongate arm may comprise an integral part of the cutting head. When the cutting head is aligned with the housing of the cutting device, the elongate arm is preferably retracted into a longitudinal recess in the housing. As the cutting head pivots on the fulcrum of the housing, the cutting means engages with the wall of the casing and the free end of the arm pivots out from the recess to engage with the wall of the casing at a position opposite to the cutting means. Preferably, a traction means, for example, a wheel or roller is provided at the free end of the elongate arm to allow the arm to move over the wall of the casing.

Where the cutting means functions by melting or vaporizing metal (for example, is a laser or a means for producing an electric spark or arc) the cutting head pivots on the fulcrum of the housing until the cutting means is in close proximity with the wall of the casing. Suitably, a biasing means is omitted from the cutting device as there is no requirement to urge the cutting means against the wall of the casing.

Preferably, the cutting device may be provided with a connector for the cable, coiled tubing or electric drill string. Preferably, the connector is releasable from the cable, coiled tubing or electric drill string.

Preferably, the cutting device is provided with an anchoring means for locking the cutting device in place in the wellbore. Suitably, the anchoring means is provided at or near the upper end of the cutting device, for example, on the housing or the connector. Preferably, an electrically operated stepper motor is located at or near the upper end of the housing at a position below the anchoring means. After setting the anchoring means, the stepper motor may be operated to rotate the housing about its longitudinal axis while the cable, coiled tubing or electric drill string remains stationary thereby allowing the cutting head to be orientated in the wellbore. It is also envisaged that the stepper motor may be used to move the cutting head around the circumference

of the casing such that the cutting means removes a transverse section of the casing.

Preferably, the cutting device is provided with a traction means thereby allowing the cutting device to be moved through the wellbore to form a window in the casing. Preferably, the window that is formed in the casing of the wellbore has a width of 3 to 9 inches and a length of 10 to 20 feet. Where the longitudinal axis of the wellbore is substantially vertical, the traction means may allow the cutting device to move in an upwards or downwards direction in the wellbore, preferably in an upwards direction.

Preferably, the connector comprises an elongate telescopic part comprising at least one section of tube that is capable of sliding into another section of tube. Preferably, an upper and a lower anchoring means are arranged on the connector above and below the telescopic part respectively. Preferably, each anchoring means comprises a set of radially extendible rams, for example, hydraulic rams or electrically operated rams. Preferably, each set of rams comprises 2 to 4, preferably, 3 radially extendible rams that are spaced apart around the connector.

The cutting device may be lowered into the wellbore with the telescopic part of the connector in its extended state. Once the cutting device is at the selected location in the wellbore, the upper anchoring means on the connector may be set and the stepper motor used to orientate the cutting head in the wellbore. The cutting head is then pivoted so that the cutting means moves to a position adjacent the wall of the casing. The cutting head may then be moved upwardly in the wellbore by gradually driving the telescopic sections of the connector together, setting the lower anchoring means, releasing the upper anchoring means, extending the telescopic part, resetting the upper anchoring means and releasing the lower anchoring means. This procedure may be repeated several times until the window in the casing is of the desired length, for example, 10-20 feet.

Alternatively, the cutting device may be lowered into the wellbore with the telescopic part of the connector in a contracted state. Once the cutting device is at the selected location in the wellbore, the lower anchoring means may be set and the stepper motor used to rotate the cutting device such that the cutting means on the cutting head is correctly orientated in the wellbore. The cutting head is then pivoted such that the cutting means is moved to a position adjacent the wall of the casing. The cutting head may then be moved upwardly in the wellbore by extending the telescopic sections of the

connector, setting the upper anchoring means, releasing the lower anchoring means and gradually driving the telescopic sections of the connector together. The lower anchoring means may then be reset, and the procedure may be repeated several times until the window in the casing is of the desired length, for example, 10-20 feet.

Suitably, sensor(s) are provided on the cutting device for monitoring, amongst other parameters, cutting diagnostics and/or diagnostics associated with movement of the traction means (hereinafter "tractor diagnostics"). The rate of cutting through the casing and the rate at which the device is moved through the wellbore may be adjusted in response to changes in the cutting diagnostics and tractor diagnostics respectively. Preferably, the cutting rate and the rate of movement of the cutting device through the wellbore is automatically adjusted in response to changes in these diagnostics.

Preferably, a guide means is suspended from the cutting device, for example, by a releasable latch means. Preferably, the guide means is a whipstock. By whipstock is meant a device having a plane surface inclined at an angle relative to the longitudinal axis of the wellbore. Suitably, the guide means may be locked in place in the wellbore via extendible arms that are capable of engaging with the walls of the casing. Suitably, the guide means, with its arms in their non-extended state, has a maximum diameter smaller than the inner diameter of the production conduit, thereby allowing the cutting device and attached guide means to pass through the production conduit to the selected location in the wellbore. Once the guide means has emerged from the bottom of the hydrocarbon fluid production conduit and is positioned immediately below the selected location in the wellbore where it is desired to form the window for the side-track or lateral well, the guide means is orientated in the wellbore using the stepper motor and is locked into place in the casing via the extendible arms. The guide means in then released from the cutting device.

Following completion of the cutting operation, the cutting device is lowered down the wellbore to reattach the guide means thereto. The arms on the guide means are then retracted and the cable, coiled tubing or electric drill string may be pulled from the wellbore until the guide means is aligned with the window in the casing. The guide means is then locked in place in the wellbore via the extendible arms before being disconnected from the cutting device. The cutting device may then retrieved from the wellbore by pulling the cable, coiled tubing or electric drill string. Alternatively, the

traction means of the cutting device may be operated until the guide means is aligned with the window in the casing. It is also envisaged that the cutting device may be retrieved from the wellbore using the traction means.

Following the retrieval of the cutting device, a drilling device may be lowered into the wellbore, through the production conduit, suspended on a cable, coiled tubing or an electric drill string until the drilling device encounters the guide means. The guide means then causes the drilling device to deflect from the original trajectory of the wellbore into the window formed in the casing such that operation of the drilling device results in the drilling of a side-track or lateral well. Where the guide means is provided with a fluid by-pass, the guide means may remain in the wellbore following completion of drilling of the side-track or lateral well. The fluid by-pass allows produced fluid from the original wellbore to continue to flow to the surface through the production conduit. Preferably, the guide means is collapsible, for example, has retractable parts and is capable of being retrieved through the hydrocarbon fluid production conduit when in its collapsed state, for example, by lowering a cable having a latch means located at the lower end thereof into the wellbore through the production conduit, connecting the guide means to the cable via the latch means and pulling the cable from the wellbore.

According to a preferred aspect of the present invention there is provided a method of milling through a casing of a wellbore at a selected location in the wellbore comprising:

passing a remotely controlled milling device comprising an elongate housing, a rotatable mill head having cutting surfaces, and a biasing means to the selected location in the wellbore;

pivoting the mill head on a fulcrum located on the housing about an axis transverse to the longitudinal axis of the housing so that the mill head engages with the wall of the casing;

actuating the biasing means to urge the cutting surfaces on the mill head against the wall of the casing; and

rotating the mill head so that the cutting surfaces mill through the casing.

According to a further preferred aspect of the present invention there is provided a remotely operated milling device for milling through the casing at a selected location

in a wellbore, the device comprising:

an elongate housing, a rotatable mill head having cutting surfaces, and a biasing means wherein the mill head is pivotable on a fulcrum located on the housing about an axis that is transverse to the longitudinal axis of the housing and, in use, the longitudinal axis of the housing is aligned with the longitudinal axis of the wellbore, the mill head is pivoted on the fulcrum to engage with the wall of the casing and, during rotation of the mill head, the biasing means urges the cutting surfaces on the mill head against the wall of the casing.

Preferably, the milling device is provided with a traction means for moving the milling device through the wellbore. A preferred traction means comprises a telescopic connector provided with upper and lower anchoring means, as described above.

Preferably, the milling device is orientated in the wellbore using a stepper motor located at or near the top of the housing. The stepper motor also allows the mill to remove a transverse section of the casing.

Suitably, the biasing means is a biasing arm, as detailed above.

Preferably, the mill head is substantially cylindrical and has cutting surfaces located at the base of the mill head or on the lower side thereof. Where the milling device is to be used for milling a window in a metal casing, the cutting surfaces should be capable of milling through the casing by grinding or cutting the metal.

Preferably, the milling device is passed to the selected location in the wellbore suspended on a cable, coiled tubing or an electric drill string as detailed above. Suitably, the outer diameter of the mill head is less than the inner diameter of the production conduit. However, it is envisaged that the mill head may be provided with an expandable mill bit wherein the mill bit in its expanded state has a diameter greater than the inner diameter of the production conduit.

Preferably, the housing of the milling device is provided with a remotely controlled electrically powered motor for rotating the mill head. Suitably, the motor for driving the mill head has a power of 1 to 50 kw, preferably 1 to 10 kw.

Preferably, the milling device is provided with sensors for monitoring mill diagnostics such as forces acting on the mill head, the applied torque, and the temperature of the cutting surfaces. Sensors may also be provided for motor diagnostics and tractor diagnostics. Suitably, the data from the sensors is transmitted to the surface,

as described above. Suitably, the rate of milling and the rate of movement of the milling device through the wellbore is adjusted, preferably automatically, in response to changes in these diagnostics.

The present invention will now be illustrated with the aid of the following figures.

Referring to Figure 1a, a wellbore 1 has a metal casing 2 fixed to the wellbore wall by a layer of cement (not shown). A hydrocarbon fluid production conduit 3 is positioned within the wellbore 1 and a packer 4 is provided at the lower end thereof to seal the annular space formed between the conduit 3 and the casing 2. A remotely controlled electrically powered milling device 5 having a guide means 6, for example, a whipstock, attached to the lower end thereof via a releasable latch means (not shown) is passed into the wellbore 1 through the hydrocarbon fluid production conduit 3 suspended on a reinforced steel cable 7 comprising at least one electric conductor wire (not shown). The milling device 5 comprises a connector 8 for the cable 7, an elongate housing 9, a pivotable mill head 10 having cutting surfaces (not shown) and an elongate biasing arm 11. The connector 8 is provided with an upper set or rams 12 and a lower set of rams 13, positioned above and below telescopic sections 14 of the connector. An electrically operated stepper motor 15 is located at or near the top of the housing 9 thereby allowing the housing and mill head 10 to be rotated about their longitudinal axis, with the connector 8 and cable remaining stationary. The housing 9 is provided with an electrically powered motor 16 arranged to drive the mill head 10. The mill head 10 is capable of pivoting about a fulcrum 17, for example, a knuckle joint or universal joint, provided at the lower end of the housing 9. The elongate biasing arm 11 is connected to the upper end of the mill head 10 with the arm retracted into a recess in the housing 9. The arm 11 is provided with a traction means 18, for example, a wheel or roller.

Referring to Figure 1b, the milling device 5 is locked in place in the wellbore 1 at the selected location via the upper set of rams 12 with each ram extending radially outwards to engage with the walls of the casing 2. The stepper motor 15 is then used to correctly orientate the mill head 10 and guide means 6 in the wellbore 1.

Referring to Figure 1c, the guide means 6 is locked in place in the wellbore 1 via extendible arms 19 before releasing the guide means 6 from the milling device 5.

Referring to Figure 1d, the mill head 10 is pivoted on the fulcrum 17 of the housing 9 about an axis transverse to the longitudinal axis of the housing such that the mill head 10 engages with the wall of the casing 2 at the position where it is desired to mill the window and the traction means 18 on the elongate biasing arm 11 engages with the wall of the casing 2 at a location opposite the mill head 10. The mechanism for pivoting the mill head 10 and associated biasing arm 11 about the fulcrum 17 is electrically operated. The mill head 10 is then rotated to mill through the casing 2 and cement of the wellbore.

Referring to Figure 1e, a window 20 of the desired size may be milled in the casing by gradually driving the telescopic sections 14 of the connector together thereby causing the biasing arm 11 to move upwardly over the wall of the casing (via the traction means 18) and the cutting surfaces on the mill head 10 to extend the window in an upwards direction. If necessary, the size of the window 20 may be further increased by engaging the lower set of rams 13 on the connector 8, releasing the upper set of rams 12, extending the telescopic sections 14 of the connector 8, engaging the upper set of rams 12 and releasing the lower set of rams 13. This procedure may be repeated several times until the window 20 is of the desired size.

Referring to Figure 1f, after the milling operation has been completed, the mill head 10 is pivoted about the fulcrum 17 until the longitudinal axes of the mill head 10 is aligned with the longitudinal axis of the housing and the elongate biasing arm 11 is retracted into the recess in the housing. The lower set of rams 13 is then released and the milling device is lowered through the wellbore 1 to reattach the guide means 6 to the milling device. The arms 10 on the guide means 6 are then retracted and the milling device is moved upwardly in the wellbore until the guide means 6 is aligned with the window 20 milled in the casing 2.

Referring to Figure 1g, the guide means 6 is locked into place in the wellbore 1, adjacent the window 20, via the extendible arms 19 before being detached from the milling device.

Referring to Figure 1h, the milling device is retrieved from the wellbore 1 by pulling the cable. A drilling device may subsequently be run into the wellbore 1 through the production conduit 3. The guide means 6 deflects the drilling device through the window 20 to drill a side-track or lateral well.

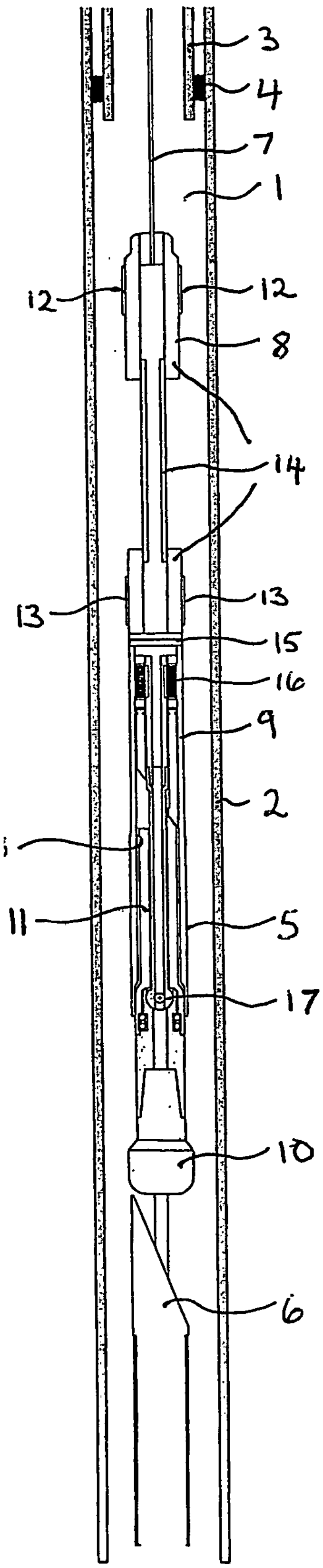

Fig 1a

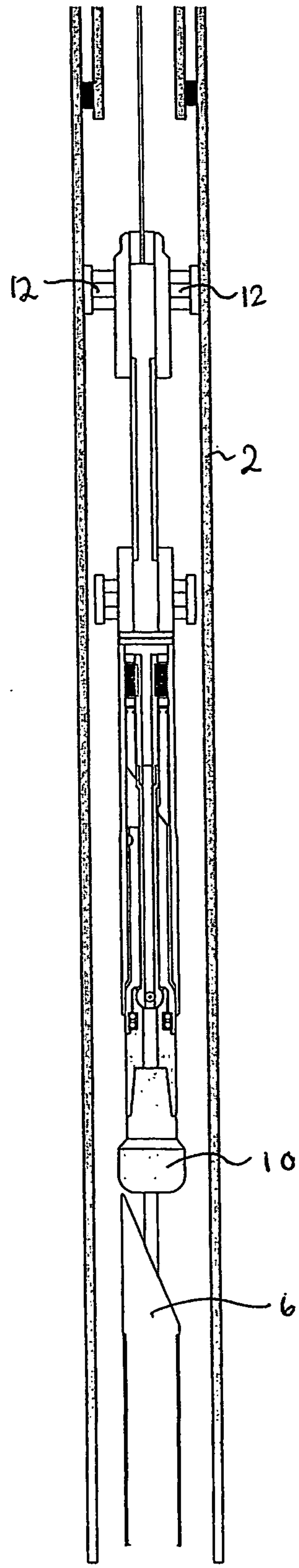

Fig 1b

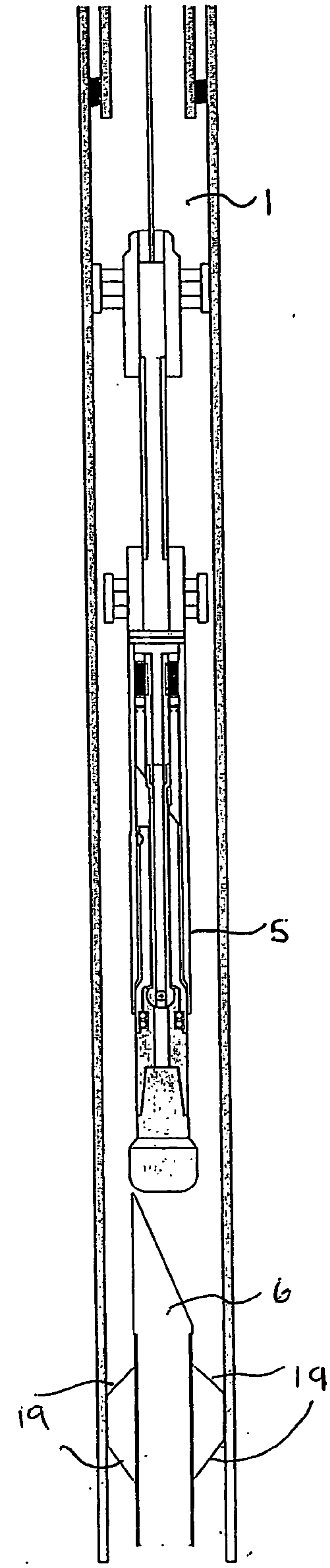

Fig 1c

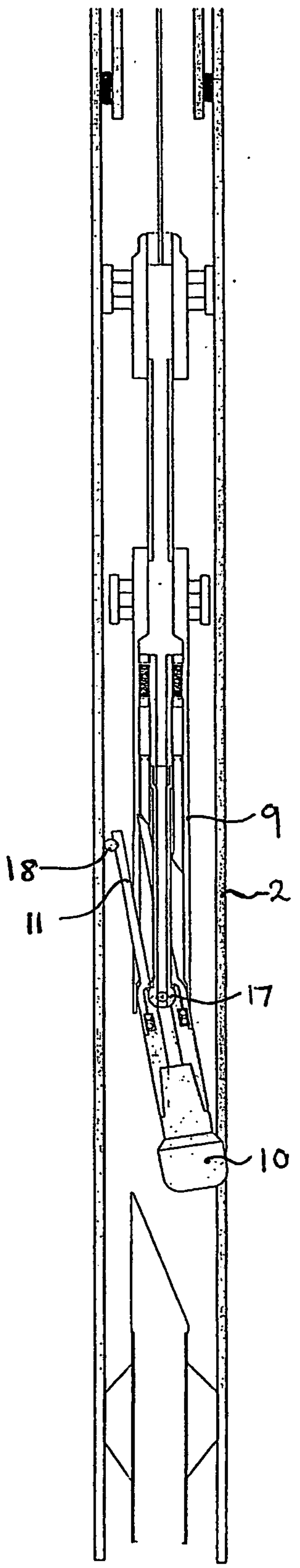

Fig 1 d

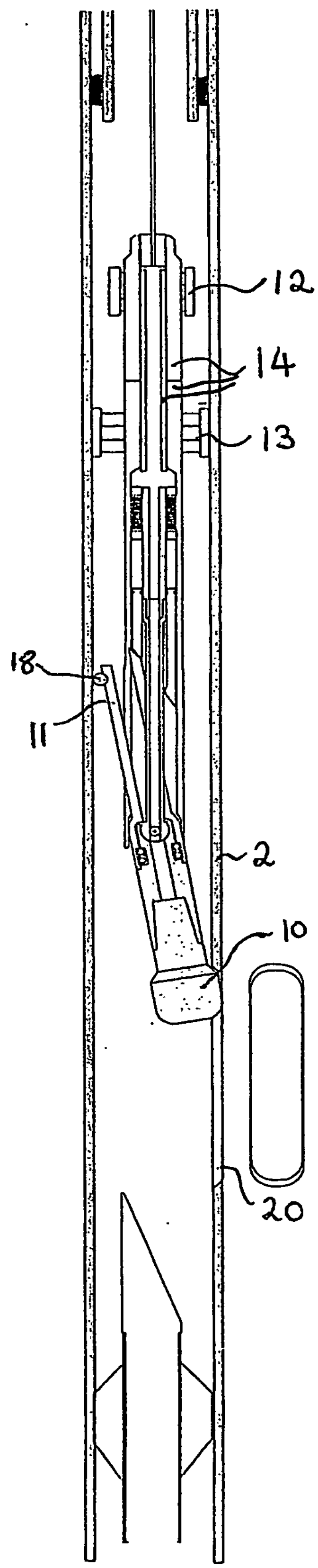

Fig 1 e

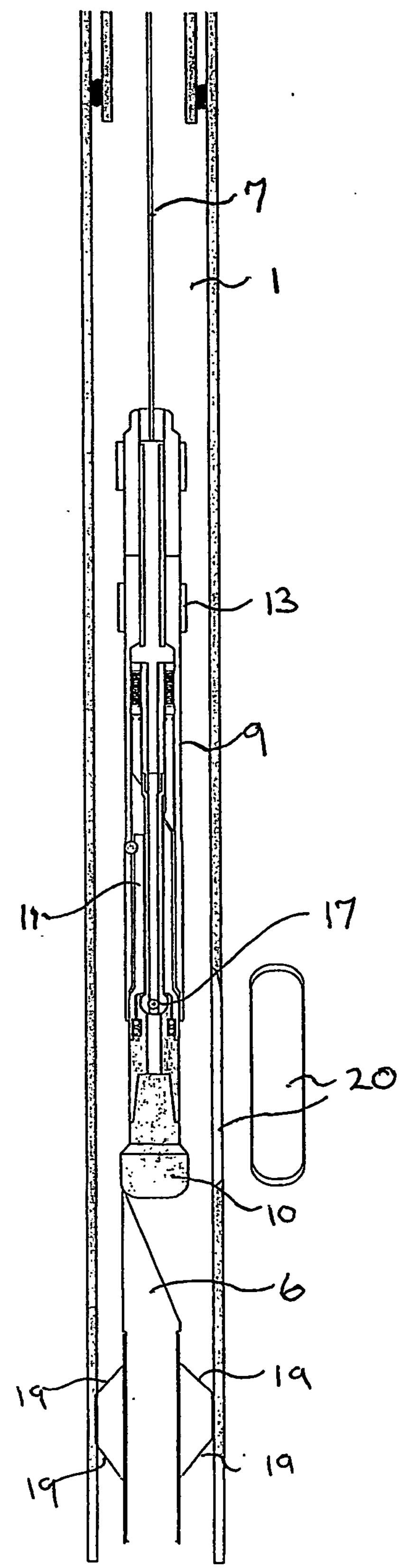

Fig 1 F.

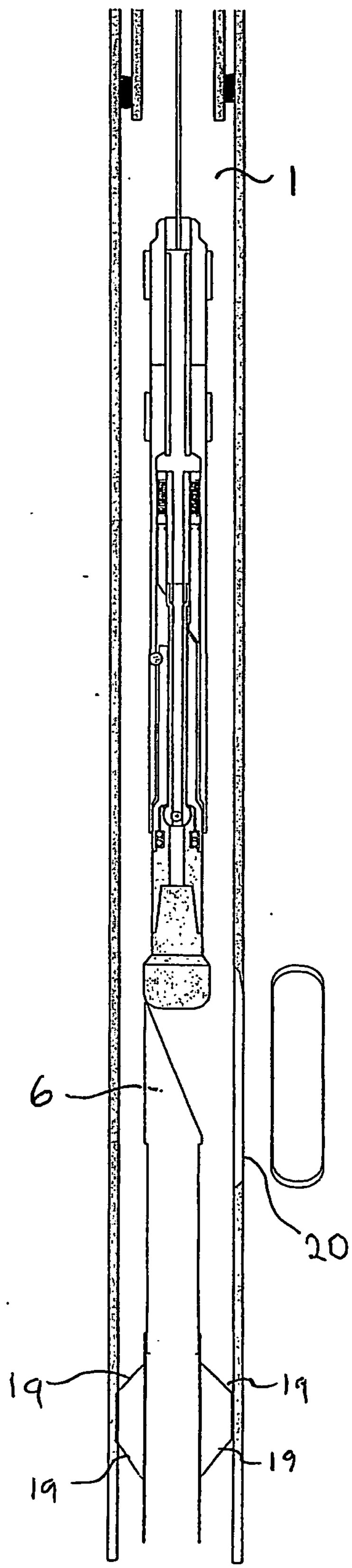

Fig 1 g

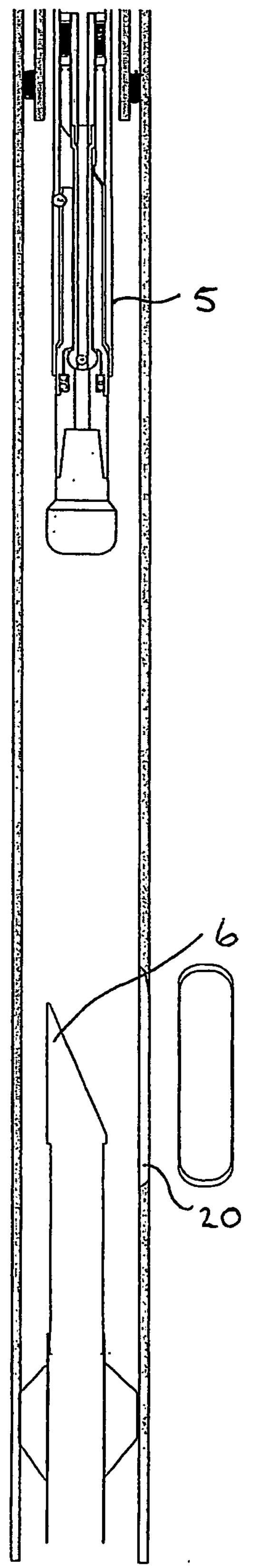

Fig 1 h

PCT Application
GB0304785